UTAH GEOLOGICAL SURVEY

SURVEY NOTES

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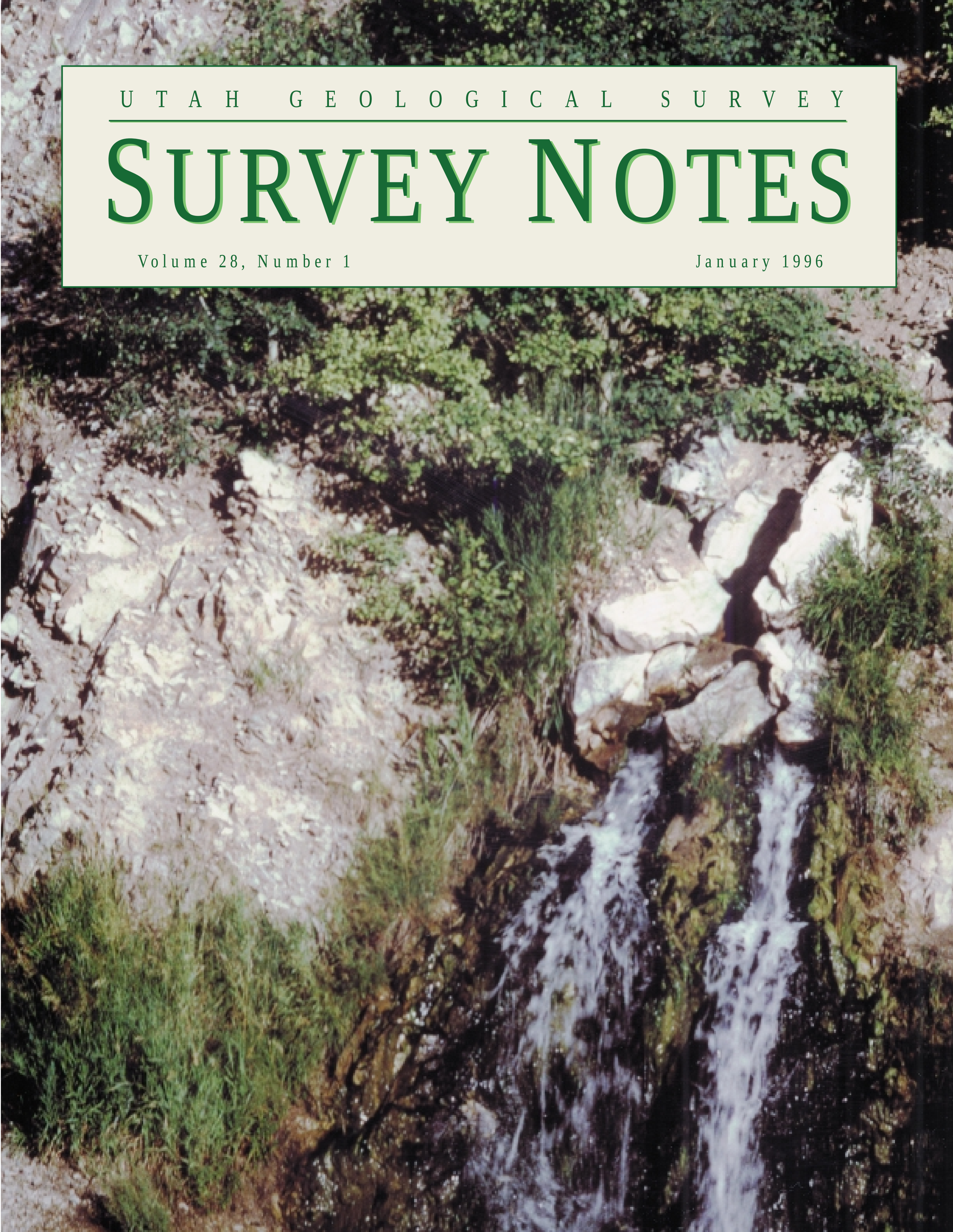

Cover photo: Spring flowing from the Weber Quartzite in Big Cottonwood Canyon. Photo by Gary Christenson.

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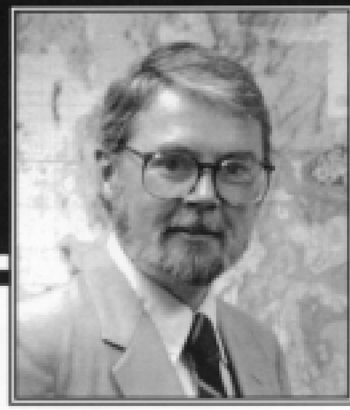

The Director's Perspective

by M. Lee Allison

Governor Leavitt recently called for a state-wide growth summit to look at pressures on transportation, water, and open space as Utah's cities and towns face unprecedented growth in the 1990s. An issue commonly overlooked when considering how land is used is geologic hazards. This Director's Perspective column is turned over to **Bill Lund** and **Gary Christenson**, UGS Deputy Director and Applied Geology Program Manager, respectively, who prepared the following UGS commentary for Governor Leavitt's consideration on the use of open space to mitigate geologic hazards. I believe it represents a win-win situation for Utah and its citizens.

PRESERVING OPEN SPACE

An Effective Means to Mitigate Geologic Hazards

W. R. Lund and G. E. Christenson

Utah is experiencing rapid growth and urbanization, particularly along the Wasatch Front and in the southwestern part of the state. With growth have come pressures: pressure to build in attractive but often hazardous areas and pressure to maintain Utah's rural, uncrowded life-style. By carefully selecting and preserving areas of open space, it is possible to simultaneously mitigate certain geologic hazards and create the open environment so important to Utah's residents.

Among the geologic hazards that can be avoided through the careful designation of open space are active faults, landslides, problem soils, debris flows, and floods. Areas subject to these hazards have been identified along much of the Wasatch Front and in many other parts of the state. Some geologic-hazard areas already have been wisely designated as open space. Fault Line Park in Salt Lake City provides a protective setback for buildings along the Wasatch fault. Rotary Glen Park at the mouth of Emigration Canyon was established in part to provide a buffer for landslide hazards along the bluff south of Emigration Creek. The flood plain of the Virgin River through St. George was designated the Virgin River Parkway both to reduce flood hazards and to provide a natural area suitable for hiking and biking. In California, open space is used extensively to mitigate geologic hazards. Active fault zones especially are now easily identified in recently developed areas by the distribution of parks, golf courses, and natural areas.

Development in hazard areas requires detailed geologic study, followed by often expensive and sometimes risky hazard-reduction measures. In many instances, greater incorporation of open space into development plans could effectively mitigate (avoid) hazards and contribute to an open, uncluttered environment. The net effect would be a cost savings both to the public and private sectors, greater safety for Utah's citizens, and preservation of an important aspect of the Utah way of life.

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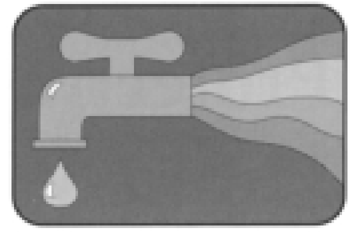


Ground-water Studies in the Applied Geology Program

by Gary E. Christenson and Mike Lowe

Background

The Applied Geology Program (AGP) performs geologic-hazards and ground-water studies to help protect the health and safety of Utah citizens. The balance between these two types of studies and the scope of projects have varied over the years. In the 1970s and early 1980s, emphasis was on site-specific studies of both types, mostly for local governments and state agencies. Most ground-water projects at that time involved helping local governments site wells and develop springs; advising city/county health departments and the Utah Department of Health's then Division of Environmental Health in siting waste-disposal facilities (septic tanks, landfills, lagoons); and assessing the potential for ground-water contamination, mostly from septic tanks. Projects were chiefly site-specific to answer immediate questions.

As the former Division of Environmental Health (now the Department of Environmental Quality [DEQ]) began hiring their own geologists in the mid-1980s, their need for assistance in ground-water studies declined. Additionally, the Utah Divisions of Water Resources (DWRe) and Water Rights (DWRi), the Utah State University Water Research Lab (UWRL), and the U.S. Geological Survey (USGS) Water Resources Division (WRD) were all actively involved in ground-water studies, so our emphasis shifted toward shallow ground water as a flood and geotechnical hazard and away from water resource and contamination issues. At about the same time, the USGS National Earthquake Hazards Reduction Program began along the Wasatch Front, and for the next decade our emphasis was principally on geologic hazards.

As Utah's population has grown, particularly in areas once rural, such as Summit and Washington Counties, the need to identify and better manage water resources has also grown. This need has highlighted the value of detailed geologic information for understanding ground-water flow and vulnerability to contamination, and for administering new regulations to protect ground-water resources. Recognizing the need for timely, accurate geologic information in ground-water studies, the Utah Geological Survey (UGS) decided in 1994 to re-emphasize ground-water studies in the AGP. Two of six AGP geologists and two contract-funded geologists, along with geotechnician support, now perform these studies.

Description

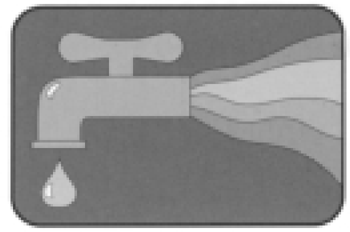
The UGS performs ground-water studies to protect the health and provide for the water needs of Utah citizens by helping identify and protect ground-water resources. We provide technical assistance to state and local governments on issues related to ground water, and identify and fill ground-water information needs.

Technical assistance to state and local governments includes identifying resources that may range from regional studies at basin-wide scales to siting of water wells. Assistance in protecting resources includes delineating drinking water source protection areas, recharge-area mapping, site evaluation for waste-disposal facilities, mapping areas for suitable waste disposal, and water-quality evaluation to identify potential sources of contamination.

UGS studies to date have identified several ground-water-information gaps which we hope to fill in the future. Improving our understanding of fracture-flow aquifers will allow more accurate delineation of recharge areas and protection zones for the large number of wells and springs in fractured-rock aquifers. A quantitative basis for determining the potential for contamination from septic-tank soil-absorption systems, based on the density of systems and/or setback distances from surface water or wells, is needed. The vulnerability to contamination of aquifers by agricultural pesticides and fertilizers is also poorly understood in Utah.

Conclusion

The UGS is bringing a needed dimension to understanding Utah's ground-water resources. The following articles discuss the various types of studies we are undertaking and give examples of studies presently underway. We look forward to continued cooperation with Utah's other water agencies in assessing and protecting our irreplaceable ground water.



Protecting Utah's Public Water Supplies

An Example from Southeastern Box Elder County

by Mike Lowe, Mark E. Jensen, Charles E. Bishop, and Bea H. Mayes

Utah's Drinking Water Source Protection Program

The Wellhead Protection Program, administered by the U.S. Environmental Protection Agency, was authorized by the 1986 Amendments to the Safe Drinking Water Act. This program assists states and local governments in protecting areas around their public-water-supply wells (or springs) from contaminants adversely affecting human health (Safe Drinking Water Act, section 1428[a]). One critical element of a wellhead protection program is delineating a scientifically valid protection area around a well or spring. Public-supply springs are included in Utah's program (called the Drinking Water Source Protection [DWSP] Program) because about 785 springs supply water to 325 public-water systems in Utah.

The Utah DWSP Program, which is managed by the Utah Department of Environmental Quality's Division of Drinking Water (DDW), specifies four protection zones. Zone 1 is a 100-foot fixed radius around the wellhead or spring collection area; zones 2, 3, and 4 are based on ground-water time-of-travel (250 days, three years, and 15 years, respectively) or ground-water flow boundaries. The Utah DWSP Program requires that public-water suppliers develop a management plan for each of the DWSP zones; higher levels of management are required in zones closer to the well or spring. The management plan should include: (1) a map and description of the DWSP zones, (2) a list of the potential sources of contamination within the DWSP zones, and (3) a plan for controlling sources of contamination within the zones.

As a service to local governments with limited resources, the Utah Geological Survey (UGS) delineates DWSP zones for cities and towns with populations of 3,300 or less for a fee of $500 plus expenses. We design and conduct aquifer tests with the system-owner's assistance, and interpret the test data to determine what areas should be in the DWSP zones. Local governments that qualify for this service are encouraged to contact the DDW or UGS.

Delineation of DWSP Zones for Wells in South Willard, Southeastern Box Elder County

The South Willard Water Company (SWWC) requested that the DDW and UGS delineate DWSP zones for two of their public-water-supply wells out of concern that a local gravel-pit operation might cause water-quality degradation in the aquifer. The wells, referred to as the "old well" and "new well," are located in southeastern Box Elder County at the base of the Wasatch Range.

Hydrogeology

Surficial sediments at the old well consist of sand, silt, and clay deposited in Pleistocene-age Lake Bonneville.

Mike Lowe, geologist with the Applied Geology Program since 1989, coordinates our ground-water projects, including recharge-area mapping, wellhead protection delineation, and ground-water studies in the Snyderville Basin (by Park City) and central Virgin River basin (by St George).

The lacustrine deposits overlie pre-Lake Bonneville alluvial-fan deposits. Surficial sediments at the new well consist of late Pleistocene to Holocene alluvial-fan deposits. The Wasatch fault zone at the mountain front just east of the new well offsets the alluvial-fan deposits. Many springs, including one used for public-water supply by the SWWC, are along the fault zone in the vicinity of the new well. The Precambrian Farmington Canyon Complex and the Cambrian Tintic Quartzite, Ophir Formation, and Maxfield Limestone crop out in the Wasatch Range to the east. These rock units generally dip 20 to 50 degrees to the east and are extensively fractured.

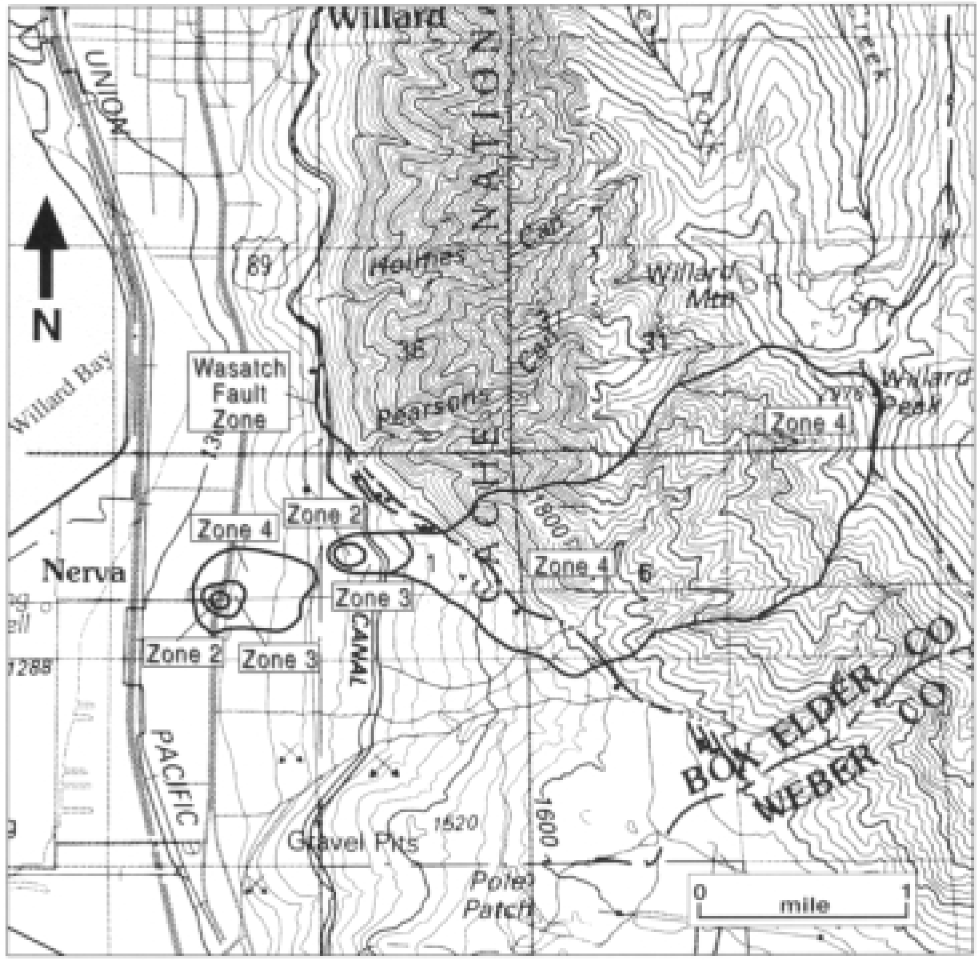
Ground-water movement in the area is generally westward from the Wasatch Range toward Great Salt

Lake which is west of the wells. The springs along the Wasatch fault zone east of the new well indicate that ground water from the Wasatch Range is being intercepted and is probably flowing to the northwest toward the well along the more permeable fault zone. The Wasatch fault zone has been shown to be a conduit for ground-water flow elsewhere along the Wasatch Front.

The recharge area for the old well is the Wasatch Range and alluvial fans to the east. The recharge area for the new well is the Wasatch Range to the east, and localized flow to the west and northwest along the Wasatch fault zone.

DWSP-Zone Delineations

To delineate the area from which the SWWC wells will get their water in 250 days, 3 years, and 15 years (DWSP zones 2, 3, and 4, respectively), we conducted aquifer tests on each well to determine how efficiently the aquifers transmit water. The rate at which water moves through an aquifer is proportional to its hydraulic conductivity, measured in units of length/time (velocity). We calculated hydraulic conductivities of 15 feet/day and 67 feet/day for the old and new wells, respectively. Based on these values, we delineated DWSP zones 2, 3, and 4 for both wells. For the old well, we took into account interference from nearby pumping wells. Because we believe that significant ground-water flow toward the new well from recharge areas in the



DWSP zones 2, 3, and 4 for SWWC old (west) and new (east) wells.

Wasatch Range is occurring along the Wasatch fault zone, the boundary of zone 4 for the new well is projected along the fault zone to the southeast. To define zone 4 for the new well, we conservatively assumed that ground-water divides in the Wasatch Range are coincident with surface-water divides in the drainages above the new well, and took the boundary of zone 4 to the Wasatch Range ridge crest. The gravel-pit operations are not currently in the protection zones for either well, indicating that the present operations are not likely to impact water quality in the wells. If operations are proposed to extend into the protection zones, their potential impacts need to be addressed in the management plan.

UGS Bookstore

Map 73, ***Major Levels of Great Salt Lake and Lake Bonneville,*** is back in print. Now available for $5.00.

C-89, ***Guide to Authors of Geologic Maps and Text Booklets,*** is great publication for those who are interested in the "how to"s of geologic mapping.

FREE TICKETS

Come to the UGS Bookstore and enter the drawing for 2 free tickets to one of the four Dinosaur Lectures.

(See page 11 for lecture topics and dates.)

First drawing .... February 9
Second drawing ... February 16
Third drawing ..... February 23
Fourth drawing .... March 1

Basin-wide Ground-water Studies

Geology and Ground Water in the Park City Area, Summit County

by Mike Lowe, Francis X. Ashland, Charles E. Bishop, and Bea H. Mayes

Introduction

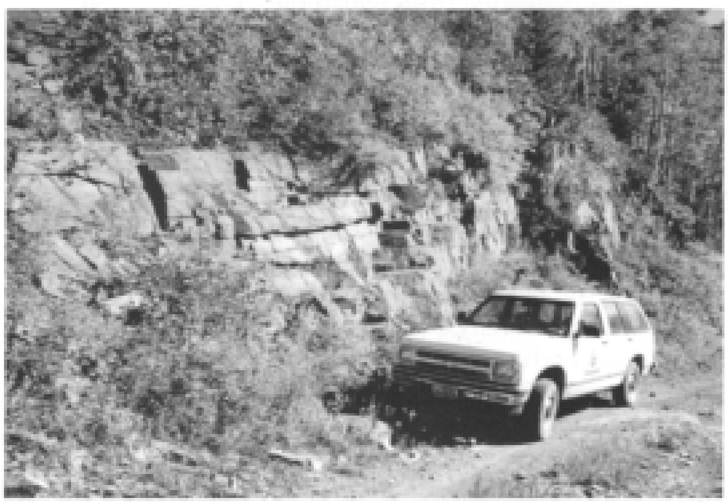
Basin-wide ground-water studies are typically conducted to help government agencies identify water resources, appropriate water rights, and protect water quality. Reconnaissance-level basin-wide studies have been completed for much of Utah, but many of these studies now need to be updated with greater emphasis placed on understanding the geology of the area. In May 1994, the Utah Geological Survey began cooperating on basin-wide studies with the Division of Water Rights and the U.S. Geological Survey. The first such study, an assessment of the relationship of geology to ground-water conditions in the Snyderville Basin (Park City area), is nearing completion. Because the population in the Snyderville Basin is rapidly growing, the availability of water is a critical factor in determining the potential for future growth.

The Utah Geological Survey's role in the Snyderville Basin study is to produce cross sections, based on compiled geologic maps and field data, to help determine the relationship of geology to ground-water resources in the area. Geology is important in defining the nature, number, and three-dimensional extent of aquifers in the Snyderville Basin. Geology is also important in identifying recharge areas, estimating water resources, and evaluating interactions between aquifers. Driller's target maps, based on the cross sections, will be included to show the extent and depth of the top of the major fractured-rock aquifers. Maps showing the thickness of the unconsolidated aquifer, based on water-well drillers' logs and seismic-refraction soundings, will also be produced. Later phases of the study by the U.S. Geological Survey will focus on aquifer hydrology and water budgets.

Hydrogeology of the Snyderville Basin

Ground water in the Snyderville Basin is in both unconsolidated valley fill and fractured rock, although most drinking-water wells draw water from fractured rock. Unconsolidated valley fill in the Snyderville Basin consists primarily of alluvial deposits along drainages and, to a lesser extent, glacial deposits. Alluvial deposits are the primary water-yielding unconsolidated aquifers. The thickness, permeability, and geometry of valley-fill deposits are their most important geologic characteristics with respect to ground-water resources.

Fractured-rock aquifers in the basin include the Jurassic Twin Creek Limestone and Nugget Sandstone, Triassic Thaynes Formation, and Pennsylvanian Weber Quartzite. The amount and characteristics of rock discontinuities, such as bedding planes, faults, and joints, are the most important factors in determining the ability of these rocks to



Outcrop of the Thaynes Formation west of Park City. UGS geologists mapped this outcrop to determine prominent fracture trends in the Thaynes aquifer.

Frank Ashland mapping fracture trends in the Nugget Sandstone at a quarry north of Park City.

yield water to wells, and can cause ground-water flow to be anisotropic. Anisotropic aquifer systems have a preferred direction of flow along bedding planes or fractures. The strike, dip, spacing, and openness of discontinuities, and type and amount of filling in faults and joints are important geologic characteristics with respect to ground-water flow in fractured-rock aquifers.

Preliminary Results

Aquifers in the Snyderville Basin include shallow, unconfined aquifers in unconsolidated surficial deposits and several, isolated fractured-rock aquifers. Unconsolidated deposits cover most of the study area, but are thin in most upland areas. In lowland areas the thickness of the deposits generally exceeds 40 feet and, based on seismic-refraction soundings and water-well drillers' logs, appears to be as much as 275 feet thick in the southern part of Parleys Park. However, the limited extent and thickness of the unconsolidated aquifers makes them secondary to the fractured-rock aquifers in terms of their potential for future development.

The fractured-rock aquifers in the study area represent a more complex system than the unconsolidated aquifers as a result of folding, faulting, and fracturing of the rocks. The fractured-rock aquifers are generally anisotropic and compartmentalized. The anisotropic character of the aquifers implies that drawdown cones of wells will be elliptical in shape as water is drawn preferentially in the direction of the most prominent water-transmitting fracture trends. Consideration of fracture patterns and characteristics is critical to understanding the interaction between adjacent wells in anisotropic aquifers. Compartmentalization results from both stratigraphic and structural separation between and within aquifers. We have identified several compartmentalized fractured-rock aquifers in the basin based on this study. Differences in fracture intensity may cause individual aquifers to be internally compartmentalized as well. Production from wells in one aquifer is unlikely to directly impact wells in an adjacent aquifer. Separate water budgets and water-management plans may need to be developed for each aquifer.

Bea Mayes taught teachers at the University of Utah and the City University of New York. Currently a geotechnician in the Applied Section at UGS, she is active in the Association for Women Geoscientists, and has volunteered for the Society of Mining, Metallurgy and Exploration, the Utah Museum of Natural History, and the Nature Conservancy. Bea assists in earthquake, debri-flow, and landslide studies and creates computer graphics.

"Glad You Asked"

by Rebecca Hylland

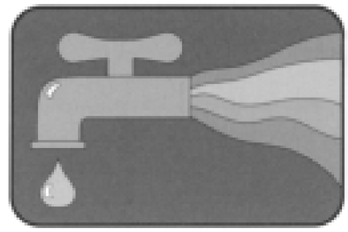
So, you have water uncontrollably seeping into your basement, or you live on a hillside and nature has moved your front walk 30 feet downslope. If your understanding of geologic processes is limited and you do not know the cause of the problem or the financial investment required for repairs, situations like these can be frustrating. Professional help to solve the problem is needed, who do you call?

For situations similar to those described above, contact the public works department (engineering, planning, or development services division) of your city or county. The problem may be one that these agencies can repair. If the city or county cannot help you, a geotechnical consultant or consulting firm should be contacted. Many are listed in the telephone book under the headings "Geologists" and "Engineers-Geotechnical." The home/property owner should contact several consultants to compare cost estimates on services.

Geotechnical consulting firms have engineers and geologists who are trained to identify and mitigate geologic hazards (slope instability, shallow ground water, and earthquake hazards, to list a few). The professional can recommend and design drainage systems for home foundations and slopes and can recommend methods to stabilize slopes and reconstruct yards. Geotechnical consultants can also determine whether or not the geologic hazard is local (your property only) or part of a larger feature with the potential to affect several pieces of property or a neighborhood.

Where does the Utah Geological Survey (UGS) fit in? We respond to emergency calls if a home, property, neighborhood, or community is in life-threatening danger from a geologic hazard. In these situations, a city or county may ask the UGS to assess the hazard, and advise them on a course of action. To document and understand geologic hazards, the UGS encourages cities, counties, and the public to inform us of events when they occur so that we may investigate the hazard if warranted.

More in this series plus other useful information can be found at the Natural Resources web site - http://www.nr.state.ut.us and look for us, the Utah Geological Survey. Our home page is at http://UTSTDPWWW.state.ut.us/~ugs/



Protecting Ground Water at Its Source through Recharge-area Mapping

by Mike Lowe and Noah P. Snyder

Introduction

Infiltration of precipitation and surface water in recharge areas is the source of most ground water in Utah. Recharge to unconsolidated basin-fill aquifers may also come from water moving laterally through consolidated rock aquifers along basin margins. Ground-water recharge areas are typically underlain by highly porous and permeable fractured rock and/or coarse-grained sediment with little ability to renew contaminated water. Because contaminants can readily enter an aquifer system in recharge areas, the siting and management of potential contaminant sources deserves special attention.

Ground-water recharge-area maps typically show: (1) primary recharge areas, (2) secondary recharge areas, and (3) discharge areas. Primary recharge areas, usually consolidated rock uplands and coarse-grained unconsolidated deposits along basin margins, have downward ground-water gradients and do not contain thick (generally thicker than 20 feet), continuous, fine-grained sediment or rock layers. Fine-grained layers thicker than 20 feet are present in secondary recharge areas, but the ground-water gradient is still downward. Ground-water discharge areas for unconfined aquifers are where the water table intercepts the ground surface, creating springs or seeps. Ground-water discharge areas for confined aquifers are where the ground-water gradient in the aquifer is upward and water is discharging to a shallow unconfined aquifer above the upper confining bed. Water from wells which penetrate confined aquifers may flow to the surface naturally (artesian wells) and in all cases stands in the well above the top of the aquifer. Studies to define recharge areas thus require a thorough understanding of the geology and hydrology of the aquifer system. The geometry and relative permeability of geologic units and levels of water in wells must be known to determine ground-water-flow directions. Water-well drillers' logs provide important data for these studies.

Working in cooperation with the Utah Division of Water Quality (DWQ), the U.S. Geological Survey (USGS) Water Resources Division (WRD), and county planning and health departments, the Utah Geological Survey (UGS) has recently completed ground-water-recharge-area maps for Heber and Round Valleys in Wasatch County, and Tooele Valley in Tooele County. With U.S. Environmental Protection Agency funding provided through DWQ, we are also mapping recharge areas for Sanpete Valley, Sanpete County; the southern Sevier Desert, Millard County; and Ogden Valley, Weber County. Discussed below are the results from the Heber, Round, and Tooele Valley studies and preliminary results from Sanpete Valley.

Heber and Round Valleys

Western Wasatch County, particularly Heber Valley, is developing rapidly. The county's ground-water supplies are presently of high quality. However, sanitary sewers serve only a portion of western Wasatch County in and near Heber City. Elsewhere, septic-tank soil-absorption systems are used and can be sources of ground-water pollution. We mapped ground-water recharge areas for the principal unconsolidated aquifers in Heber and Round Valleys so that Wasatch County could include the maps in its petition to the Utah Water Quality Board. The purpose of the petition was to officially classify the quality of the aquifers to help enact protection strategies.

Heber and Round Valleys contain predominantly coarse-grained, valley-fill aquifers, with only localized, discontinuous clay confining layers. Virtually all of Heber and Round Valleys are primary recharge areas. These factors make the aquifers vulnerable to contamination. The aquifers discharge along the northern margin of Deer Creek Reservoir and the lower reaches of streams, rivers, and canals near the reservoir.

Don't put the outhouse over the spring!

Wasatch County succeeded in classifying the aquifers as Class IA (pristine) or Class II (Drinking Water Quality). The recharge-area maps may now be used to define the area where land-use management to protect ground-water quality may be needed.

Tooele Valley

Tooele Valley is also experiencing increased development because of its proximity to Salt Lake City. Much residential wastewater treatment in Tooele Valley is in septic-tank soil-absorption systems. Some ground-water contamination has occurred in Tooele Valley, but all of the contamination sources have not been identified. In anticipation of petitioning the Utah Water Quality Board to classify its principal aquifer according to quality of ground water, Tooele County requested that the UGS,USGS WRD, and DWQ map ground-water recharge and discharge areas and water quality in Tooele Valley. This information will provide Tooele County with a basis for establishing and enforcing regulations to protect ground-water quality.

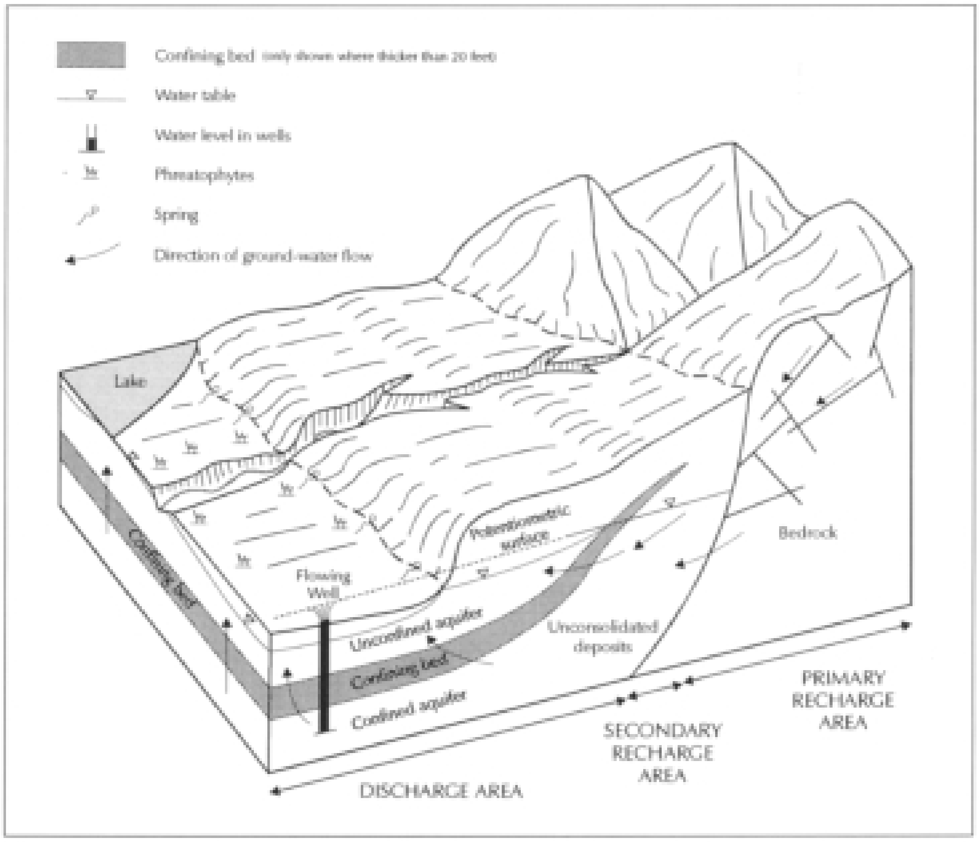
The eastern and western margins of Tooele Valley and most of the area above 4,500 feet in elevation in the southern portion of the valley (including Tooele and the Tooele Army Depot) are primary recharge areas. Only the northern part of the valley, which contains fine-grained lacustrine deposits of the Bonneville and earlier deep-lake cycles, is a secondary recharge or discharge area. Little of the principal aquifer is protected by thick, continuous, fine-grained confining layers, making it vulnerable to contamination.

Sanpete Valley

Sanpete Valley in central Utah is a rural area also experiencing an increase in residential development and agriculture, mostly on unconsolidated valley-fill deposits which are the principal drinking-water aquifer for the valley. High nitrate levels in ground water are widespread in Sanpete Valley, where several wells have been identified with greater than 40 mg/L nitrate. The maximum contaminant level (MCL) allowed under state and federal regulations for nitrate in drinking water is 10 mg/L (10 parts per million). Ground water from a city well in Moroni exceeded the MCL for nitrate during the fall of 1994. Ground water from a city well in Manti contains about 4.5 mg/L nitrate. The origin of the nitrate has not been determined, but possible sources are: (1) septic-tank soil-absorption systems, (2) agricultural fertilizer, (3) cattle and poultry (mostly turkey) ranches (feed lots, manure piles), and (4) naturally occurring nitrate. The UGS, in cooperation with DWQ, is producing recharge-area maps for Sanpete Valley which will allow state and local officials to determine if potential nitrate sources are located in recharge areas

The valley fill in Sanpete Valley consists mostly of coalescing alluvial-fan deposits along the valley margins and channel and flood-plain deposits of the San Pitch River and Silver Creek in the central portions of the valley. Fine-grained deposits exist at depth in the central part of the valley. The valley fill is thickest near the Gunnison fault zone along the western margin of the valley, where some wells have penetrated unconsolidated sediments for more than 500 feet before encountering consolidated rock.

Ground water is mostly under water-table conditions at the northern end and along the margins of Sanpete Valley, but is confined in the center where there are flowing wells. The ground water is predominantly fresh with total-dissolved-solids concentrations less than 1,000 mg/L. The primary recharge to the aquifer system is seepage from streams along the valley margins and at the northern end of the valley. Natural discharge is in the central part of the valley along the San Pitch River. Discharge also occurs from wells. In addition to recharge-area mapping, the Utah Geological Survey is planning subsequent work to sample wells, map water quality, and identify the sources of nitrate contamination so that appropriate remediation techniques can be employed.



Generalized block diagram showing relation of recharge and discharge areas in a typical basin-fill aquifer system.

Energy News

UGS Tech-Transfer Activities are in Full Swing at Recent Petroleum Industry Meeting

by Roger L. Bon

The UGS mounted a major technology-transfer effort for three UGS/industry cooperative petroleum programs at the American Association of Petroleum Geologists (AAPG) Rocky Mountain Section Meeting and Exhibition held in Reno, Nevada, July 16 - 19. The meeting was a gathering of petroleum exploration geologists from throughout the western United States. The three programs (Ferron Sandstone, Bluebell, and Paradox Basin), sponsored by the U.S. Department of Energy (DOE), are designed to increase reserves and productivity of existing oil fields and develop new technologies for finding additional petroleum.

Tech-transfer activities at the AAPG meeting consisted of: (1) oral and poster presentations on individual programs, (2) an exhibit illustrating current progress on each program, and (3) release of the latest issue of Petroleum News, a newsletter oriented to the oil and gas industry. Workshops, field reviews, and special symposia are additional activities that have taken place or are being planned as part of the tech-transfer effort.

Ten Ferron Sandstone and Bluebell presentations were given at the meeting, including a series of oral presentations describing the "results to date" of the Ferron Sandstone program. The focus of the presentations was on reservoir characterization, new field methods, and sequence stratigraphy. Oral and poster presentations for the Bluebell program focused on reservoir characterization. Equipped with high-tech illustrations and a wealth of data generated by each program, the tech-transfer exhibit unveiled its "new look." The exhibit highlighted progress on each of the three programs, utilizing computer-generated lithologic sections, deposition and reservoir models, seismic profiles, block diagrams, and program location maps.

The AAPG meeting also marked the release of the latest issue of Petroleum News. In addition to the program summaries, the newsletter contains a summary on coalbed-methane development in eastern Utah and an article describing the results of a very successful water-flood project (Monument Butte) in the Uinta Basin. The newsletter also includes a listing of well locations for cuttings and core samples that have recently been donated to the UGS Sample Library.

"With new data and new ideas being generated from each program almost daily, our goal is to synthesize and transfer these data and the resultant new technologies in an efficient and expedient manner to all interested parties," said Roger Bon, technology-transfer coordinator. "Through these research and demonstration programs, we can have a positive effect on the on-going effort to curb our nation's and our state's declining oil production and reserves."

For additional information on the programs or to receive a copy of Petroleum News contact Roger Bon at 801-467-7970.

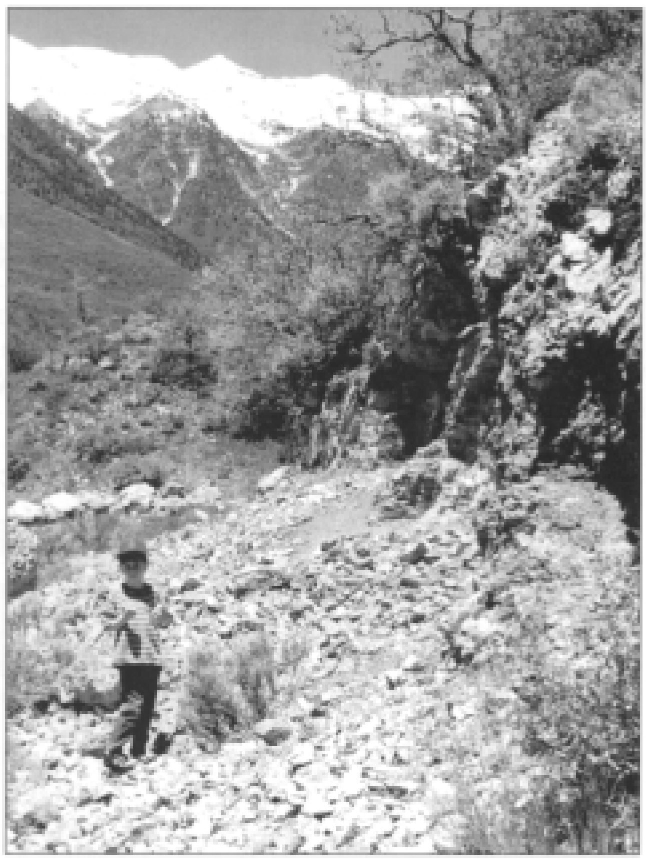
You can also download the newsletter from http://www.nr.state.ut.us. Look for UGS, and under Oil Patch you'll find Petroleum News and other energy-related information.

The Rockhounder

"Onyx" near Mount Nebo, Juab County

by Christine M. Wilkerson

Geologic information: Although the rocks at this site are commonly called onyx (on'-iks) or onyx marble, they are not true onyx. True onyx is parallel-banded chalcedony, a cryptocrystalline (microscopic crystals) variety of quartz. The Mt. Nebo deposit consists of reddish-orange and cream-colored banded calcite. Calcite is composed of calcium carbonate ($CaCO_3$). Banded calcite forms when calcium carbonate precipitates (separates out) from a solution of dissolved calcium carbonate and ground water. The calcium carbonate is deposited within a large opening or fissure in the mother rock and parallel bands are created as additional calcium carbonate precipitates. The color differences between bands are probably caused by slight changes in the chemical composition of ground water during precipitation. The Mt. Nebo banded calcite can be polished and is used for decorative objects, such as bookends.



"Onyx"/banded calcite samples litter the ground at deposit near Mt. Nebo. This young rockhound is collecting a variety of colorful stones. View of the southern Wasatch Range in background.

How to get there: Travel about 5 miles east of Nephi on State Highway 132 to the Mt. Nebo Scenic Loop intersection. Turn north (left) onto the Mt. Nebo road and travel approximately 3 miles until you reach the turnoff to the Mt. Nebo Scenic Loop. Stop and park in the open space on the west (left) side of the main road.

Where to collect: Walk about 0.2 miles up the Mt. Nebo Scenic Loop road until you see faint tracks on the northwest (left side of road). Follow the trail uphill about 0.5 miles to the collecting site, a red and white knoll west (left) of the trail. Go around to the other side of this knoll for the best collecting. Numerous large and small rock samples litter the ground on the west side of the knoll. To remove a sample from the outcrop you will need a rock hammer or a hammer and chisel. Please remember to wear your safety glasses.

Useful maps: Nephi 1:100,000-scale topographic map, Nebo Basin 7.5-minute topographic map, and a Utah highway map. Topographic maps can be obtained from the Utah Geological Survey, 2363 South Foothill Drive, Salt Lake City, UT 84109-1491, (801) 467-0401.

Land ownership: Uinta National Forest.

Collecting rules: The casual rockhound or collector may take small amounts of gemstones and rocks from unrestricted federal lands in Utah without obtaining a special permit if collection is for personal, non-commercial purposes. Collection in large quantities or for commercial purposes requires a permit, lease, or license.

Miscellaneous: Beautiful wildflowers make spring a good season to visit this deposit. A hat, hiking shoes, and water are recommended. Bring a rock hammer and protective eyewear if you intend to break pieces of rock. Please carry out your trash. Have fun collecting!

The Rockhounder can be found at http://www.nr.state.ut.us. Just look for our page, Utah Geological Survey.

The Zion Canyon Landslide, Zion National Park

by Barry J. Solomon

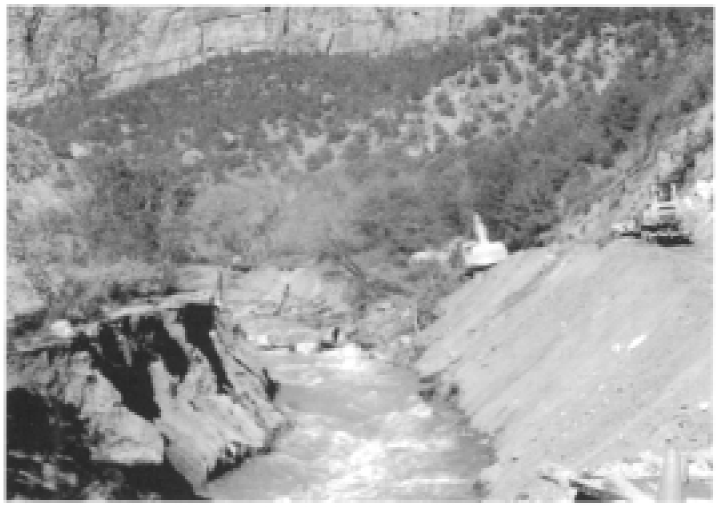
On April 12, 1995, a landslide on the west bank of the North Fork of the Virgin River in Zion Canyon, Zion National Park, dammed the river and formed a pond about 20 feet (6 m) deep. About 1,000 campers were evacuated from the Watchman and South campgrounds downstream in case sudden dam failure caused flooding. Drinking-water supplies were temporarily disrupted in the campgrounds and in the town of Springdale, 3 miles (5 km) south of the landslide. The river gradually cut around the toe of the slide and drained the pond, but caused no downstream flooding. As the river flowed around the slide it eroded the east river bank and washed out a 600-foot (180 m) section of the adjacent Zion Canyon Scenic Drive. The road provides the only access to Zion Lodge, where more than 300 guests and lodge employees were stranded without water, sewer, electricity, or phone service. A one-lane, temporary road was cut into the slope east of the landslide, on the east side of the river, to evacuate people from the lodge.

The landslide moved southeast from the face of Sand Bench, a 600-foot (180 m) bluff at the base of a prominent sandstone cliff. The cliff rises another 2,200 feet (670 m) to an elevation of 7,043 feet (2,147 m) at the peak of The Sentinel. Prehistoric landslide deposits form the bulk of the bluff. The 1995 landslide is the latest in a series of historical slope failures in the prehistoric landslide. Previous researchers noted two "major slides" in the older slide mass, one in 1923 and the other in 1941. Another landslide reportedly happened here during the Richter magnitude (M_L) 5.8 earthquake of September 2, 1992. That earthquake, with an epicenter 5 miles (8 km) southeast of St. George, also triggered a large landslide in Springdale.

The landslide of April 12, 1995, and a generalized outline of the prehistoric landslide near The Sentinel, Zion Canyon.

The 1995 landslide is a complex slide with an earth slump at its head and an earth flow at its toe. The slide mass measures roughly 500 feet (150 m) from the main scarp to the toe, and is about 150 feet (45 m) wide. The total volume of material involved is about 110,000 cubic yards (84,000 m^3). The landslide has a clearly defined main scarp as high as 75 feet (23 m), and a sharp secondary scarp about 30 feet high (9 m), indicating that the upper part of the landslide moved in two coherent pieces.

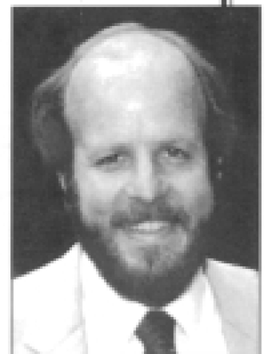
Increased precipitation apparently triggered the landslide. Precipitation was 189 percent of average for the water year through April 14, 1995 in the Dixie region. Weather records from Zion National Park show no precipitation in early April, immediately prior to the landslide, but precipitation was much higher than average during March. Average precipitation in March is 2.80 inches (7.11 cm), but 5.73 inches (14.55 cm) fell during



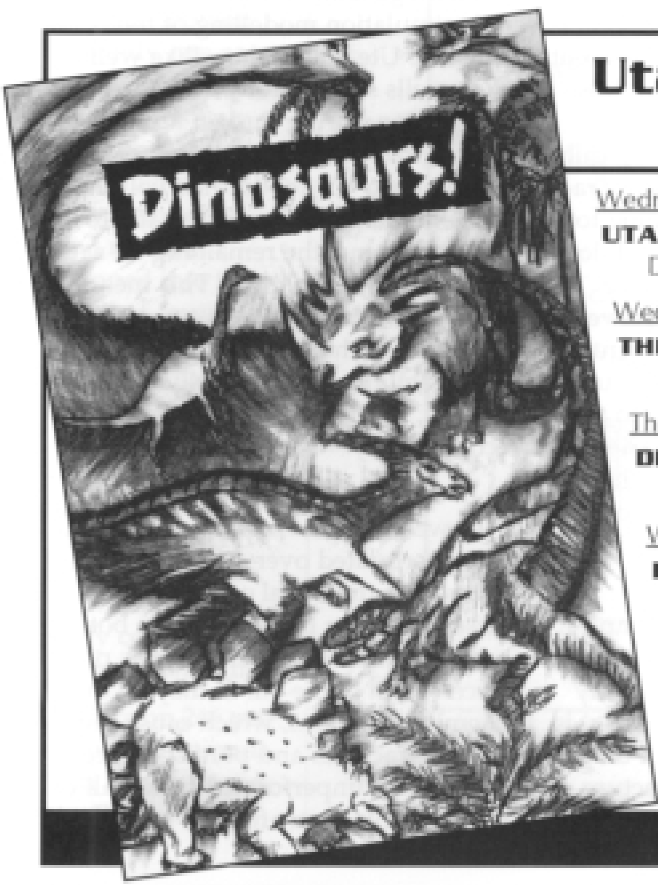
Erosion damage to Zion Canyon Scenic Drive, which originally ran through the center of the picture above the present river course. The landslide displaced the North Fork of the Virgin River from the west wall to the east wall of the canyon, where construction equipment cuts an emergency road into the adjacent slope.

that month in 1995. Much of this, 3.40 inches (8.64 cm), fell during a six-day period early in the month, culminating in 1.06 inches (2.69 cm) of precipitation on March 6, 1995.

Increased tourism in Zion National Park and rapid development in the town of Springdale at the park's southern entrance highlight a critical need to evaluate the long-term landslide hazard in Zion Canyon. The Utah Geological Survey, with the cooperation and financial assistance of Springdale and the Utah Permanent Community Impact Fund Board, is conducting an evaluation of all geologic hazards, including landslides, in the town in lower Zion Canyon. The U.S. Geological Survey is proposing a program to evaluate the long-term landslide hazard in upper Zion Canyon in Zion National Park. These efforts will significantly contribute to ensuring the safety of residents and tourists from landslide and other geologic hazards in southwestern Utah.



Barry Solomon is a geologist in the Applied Geology Program at the Utah Geological Survey. He has 21 years work experience as a geologist, including 7 years as an engineering geologist at the Utah Geological Survey and 5 years at private engineering/geological consulting firms in southern California, Ohio, and Texas. He has a B.A. degree in geology from the University of California, Santa Barbara, and an M.S. degree in geology from San Jose State University. Barry has published extensively in the field of geology, and is currently involved in studies of the geologic hazards of Springdale, Utah, the site of a destructive landslide caused by the St. George earthquake of 1992, and the surficial geology of the West Cache fault zone, Cache County, Utah.



Utah Museum of Natural History 1996 Winter Lecture Series

Wednesday, February 21

UTAH: A TREASURE CHEST OF DINOSAURS

Dan Chure, Dinosaur National Monument

Wednesday, February 28

THE REAL "JURASSIC PARK"-NEW IDEAS ABOUT DINOSAURS

Dr. Kevin Padian, University of California, Berkeley

Thursday, March 7

DINOSAURS: FROM MONSTERS TO BIRDS

Dr. John R. Horner, Museum of the Rockies

Wednesday, March 13

DINOSAUR EXTINCTION: MYTHS, CONTROVERSIES, & FACTS

Dr. J. David Archibald, University of California, San Diego

Location: University of Utah, Fine Arts Auditorium, 1530 E. South Campus Dr.
Time: All lectures, 7:30 p.m.
Admission: $5.00 per lecture
UMNH Members: Museum members may purchase a series ticker for $15.00.

For more information, please call 581-6928.

Co-sponsored by The Utah Geological Survey

Bluebell Project to Test Well-Completion Techniques

by Craig D. Morgan and Bryce T. Tripp

The U.S. Department of Energy approved funding of Budget Period II of the Utah Geological Survey's Bluebell project to begin October 1, 1995. The Bluebell project is a five-year study designed to demonstrate "increased oil production and reserves from improved completion techniques in the Bluebell field, Uinta Basin, Utah." Completion techniques are various mechanical and chemical treatments of a well to increase the amount of petroleum produced. These techniques are used immediately after the well is drilled and periodically after it has produced for some time (termed a recompletion).

Budget Period I was the reservoir-characterization phase of the project. Reservoir characterization consisted of studying the geology and engineering characteristics of the rocks in producing wells and similar rocks in outcrop. Also, past completion practices were studied. These data were used to develop what is hoped to be better geologic formation evaluation practices and better well-completion techniques. Budget Period II will be a demonstration of these techniques in recompleting two wells and drilling and completing a third well.

Budget Period I outcrop studies, subsurface studies, and engineering studies by the Bluebell project team yielded or may soon yield several specific results which could help improve completion techniques used in future oil drilling in the Bluebell field. Several ideas being tested are described below.

1) Examination of outcrop and core shows that the potentially most productive reservoir rock types in the Green River and Wasatch Formations are arenites (clean sandstones) which commonly have the degree of porosity and permeability necessary to produce fluid. Intergranular permeabilities of greater than 0.1 millidarcies (a minimum cutoff value for a good reservoir) occur only when intergranular porosity is greater than 5 percent and clay content is 4 percent or less. Since clay content lowers porosity and permeability, geologists typically estimate clay content (a naturally radioactive material) by examining total gamma-ray count curves on well logs. However, project geologists have shown that total gamma-ray curves are poor indicators of clay content in Bluebell field rocks because any uranium present also contributes to the total gamma-ray count and varies independently of clay content. The Wasatch Formation generally contains less clay than the Green River Formation.

2) Analysis of outcrop, core samples, and well logs shows that all potential reservoir rock types are moderately fractured, and that fracture density is not depth related, but fracture direction is depth related. Two fracture sets, roughly at right angles to each other, occur at the surface, but in the subsurface fractures tend to be oriented NW-SE at shallow depths and E-W at deeper horizons. Most fractures in the Bluebell cores are 90 percent or more calcite filled. Knowing the fracture orientation and fracture density is crucial in designing drilling and completion programs in the Bluebell field because oil tends to flow from fractures into wells that intersect the fractures.

3) Homogenous (unfractured) reservoir-simulation modelling of the Michelle Ute and Malnar Pike wells (two wells studied for possible recompletion during Budget Phase II of the contract) showed that the wells drain only a 400-foot radius volume of the reservoir. Even in the 400-foot radius volume, the remaining oil saturations are fairly high. This means that even though there is a great deal of oil still in the reservoir, unless the permeabilities are artificially enhanced, the oil cannot be recovered economically.

4) In the Michelle Ute and Malnar Pike wells, additional geologic strata were perforated over a period of years after the initial completion to offset declining production. In both wells the first set of perforations produced most of the oil. It may be that chemical reactions, which cause plugging of fractures and pore space, continue in the unperforated rock wall of the drill hole even after the metal

tube liner is installed. Therefore, when they are eventually perforated, these zones do not produce as much as the initially opened zones or, the chemical and mechanical treatments of the well by engineers become less effective as more beds are perforated.

5) Fractured-reservoir simulations showed a radius of influence of the well on the reservoir of about 1,000 feet. Most wells in this part of the Bluebell field are drilled at one-well-per-square mile spacing, therefore little of the oil-in-place is currently being drained. Information of this type is important to regulatory agencies who determine well spacing for optimum petroleum production.

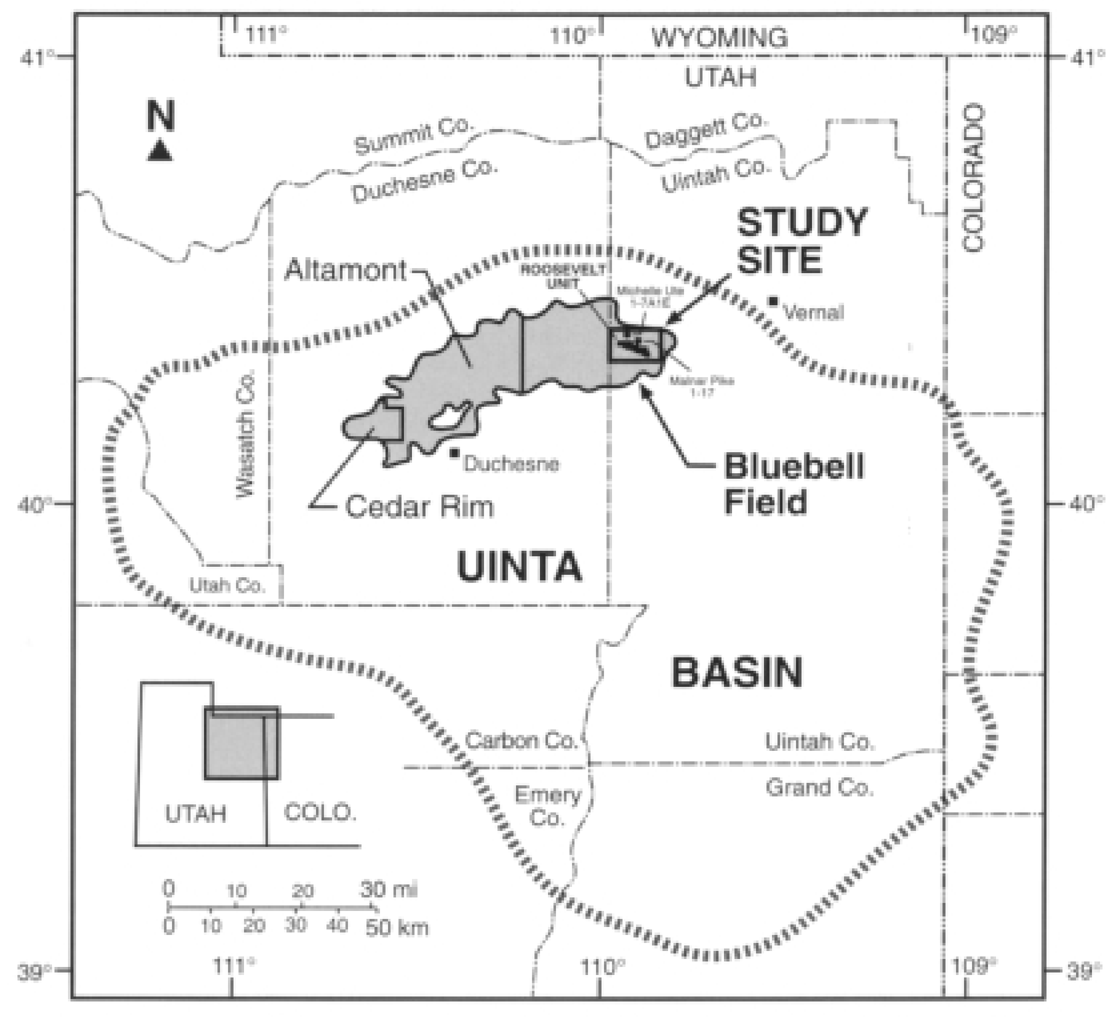
6) Recent work by Coastal Oil and Gas (ANR Production) in the neighboring Altamont oil field has shown that fluid pumped into the well to fracture the producing rocks and provide additional pathways of oil flow can result in fluids moving into only one or two highly permeable (intensively fractured?) intervals. Increasing the amount of diversion material pumped into the well has improved the number of potentially productive beds that Coastal is able to treat. Coastal's results also indicate that the original fluid pressure zones in the well may partially control flow of treatment fluid.

7) Data on 246 previous well stimulation treatments in the Bluebell field are being evaluated by Bluebell team members; findings from these studies will be used in choosing fluids, additives, volumes, and rates for the stimulation treatments scheduled for Budget Period II of the Bluebell project.

8) Cased-hole geophysical logs will be run in the demonstration wells, generating data to be used with other information to select individual beds for stimulation using an extended-reach, hydro-jet lance tool. This tool can be used to drill horizontally as much as 10 feet into selected beds. This technique may improve future production from Bluebell wells by opening more productive surface area in specific zones of the oil well and providing a fluid pathway through the zone of formation damage (a zone in the drill hole of low porosity and permeability with accompanying poor petroleum production, usually caused by mechanical and chemical processes).

The Bluebell field has large petroleum resources that can be more efficiently produced. Improved completion and recompletion techniques developed in the Bluebell project can help prevent premature abandonment of wells that are now only marginally profitable.

This article and others related to energy can be found at http://www.nr.state.ut.us. Look for UGS and Oil Patch.



Location of Bluebell project area, Uinta Basin, Utah.

Teacher's Corner

By Sandy Eldredge

Student Volunteer opportunities

Are there any outstanding high-school students out there who would like to volunteer some time during their summer to help a geologist(s)? Such an experience can be fun and rewarding. Last summer, we had the help of Brad Didericksen from West Jordan High School. Brad was able to go on field trips, work on computer programs and data input, see the Wasatch fault up close in a trench, and do some drafting, among other things. Apparently, Brad (who is now a senior at West Jordan) had so much fun that he is continuing to work for one of the Utah Geological Survey (UGS) geologists as part of his Independent Studies course in geology this school year. The project involves plotting and mapping data to help determine the lateral extent of part of the Ferron Sandstone. The UGS "Ferron Sandstone project" aims to develop better models of river and delta sandstones and shales in order to increase oil and gas production from similar deposits. If any teachers have interested and outstanding students in the earth sciences, contact me at 467-7970 about volunteer opportunities at the UGS.

Topographic maps

The U.S. Geological Survey (USGS) has increased the price of their topographic maps to $4.00 and the UGS has had to follow suit. But the UGS offers teachers a 20% discount on most purchases, so maps may be bought for $3.20.

Other maps

The UGS now carries several other maps of educational interest:

U.S. Shaded Relief Map, USGS National Atlas Series. Color relief map showing U.S. landforms, measures 28" x 18". $4.00 ($3.20 with teacher discount).

Utah Shaded Relief Maps, Experimental Digital Shaded-Relief Maps of Utah, USGS Map I-1847, 1:1,000,000 scale. Two maps - one map is color-coded by elevation and includes towns, roads, and counties; the other map is shaded gray to display landforms. Each sheet measures 20" x 30" (actual map is smaller). $4.00 ($3.20 with teacher discount).

This Dynamic Planet, world map of volcanoes, earthquakes, impact craters, and plate tectonics, USGS and others, 1994 edition. Shows Earth's physiographic features, the current movements of its major tectonic plates, and the locations of its volcanoes, earthquakes, and impact craters. Includes descriptions of plate boundaries. Measures 58" x 41". $4.00 ($3.20 with teacher discount).

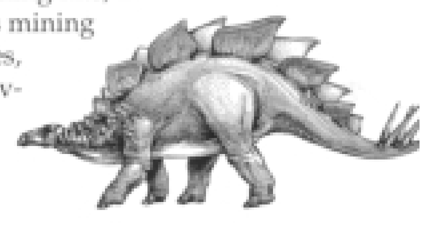
Sales hours are 8:00 - 5:00 Monday through Friday. Or call 467-0401 to place an order. To obtain your teacher discount, please identify the school you work for.

This series of articles for teachers, plus other information, can be found at http://utstdpwww.state.ut.us/~ugs/tcorner.htm

Check it out!

A dinosaur teaching kit is one of the many items available for teachers to check out from the Utah State Historical Society. The kit consists of authentic and cast specimens, slides, publications, and other teaching aids. It can be used by all age levels, but is most suited for preschool through elementary grade levels. Background information on Utah's dinosaurs and their discovery, as well as ideas and suggestions for using the items in the kit are included. The focus of the kit is on Utah during the time of the dinosaurs.

The kit may be reserved in advance, and must be picked up and returned by the user to the Utah State Historical Society Library in the Denver and Rio Grande Train Depot (300 Rio Grande, Salt Lake City, Utah, 84101) during business hours (Tuesday - Friday 10:00 - 5:00 and Saturday 10:00 - 2:00). There are no fees, but a $25.00 refundable deposit is required. Other teaching kits, including a new one on Utah's mining history, as well as video tapes, photograph exhibits, and travelling exhibits, are also available for check out. To receive a free catalog, give them a call at 801-533-3536.



Survey News

Contract Awarded

UGS is part of a consortium, headed by the Salt Lake City firm of Terra Tek, that was just awarded a contract from the U.S. Department of Energy for a proposal "Advanced fracture modeling in the Uinta Basin for optimized primary and secondary recovery." The UGS portion has Craig Morgan as project manager. University of Utah, University of California Berkeley, and a consulting company are other partners.

STATEMAP Funding

The USGS has awarded the UGS $125,000 this year for coop geologic mapping in Utah. This is the 6th highest amount given to any state and is significantly higher than our previous awards of $30-38,000.

Reorganization

The Geologic Extension Service and Paleontology/Paleocology section are upgraded to Program status effective December 18. UGS now has 5 programs, including Applied, Mapping, and Economic. Kimm Harty and David Madsen will continue as managers of their programs. This decision was made after consultation with the UGS Board, the Legislature staff, and DNR Administration.

Employee News

Jim Springer is the new public information officer for the Utah Geological Survey. A graduate of the University of Utah, he spent 20 years in Salt Lake area broadcasting, 15 years as the morning personality on radio station KSFI, FM-100. Leaving broadcasting in 1991, he went to work for the Department of Defense as a public affairs officer. While stationed in Atlanta, Georgia, Jim formed part of a team handling media relations during Operation Desert Storm and the Los Angeles riots following the Rodney King verdict. In addition to the UGS, Jim also provides public information services for the divisions of Sovereign Lands and Forestry and Oil, Gas and Mining.

Hugh Hurlow is a new geologist in the Applied Section, working on the geology of Washington County and its relation to ground-water conditions. Hugh was a Visiting Assistant Professor at the University of Montana before moving to Salt Lake City with his wife, Marilyn, and son, Evan. Hugh received his Ph.D. in geology from the University of Washington in 1992.

UGS summer of 1994 intern, **Noah Snyder**, is working on a one-year ground-water project ending in May. He is mapping recharge and discharge areas for Sanpete Valley, Ogden Valley, the southern Sevier Desert, and Castle Valley. He plans to enter graduate school in geology next fall.

Charles Williamson is a new geologic aid working in the Mapping Section at the Utah Geological Survey. He is a recent graduate in geology from the University of Utah and plans on attending graduate school in the near future.

Kimberly Waite is working in the Economic Section at the UGS as a geotechnician. She is from Farmington, New Mexico, and will be graduating from Brigham Young University with a Masters Degree in geology in April.

Kelli Bacon is the new revenue tech working in the UGS bookstore. A graduate of geology from the University of Utah, she previously worked for UPS and as a lifeguard/swimming instructor for Salt Lake County.

Dan Rivers works in the UGS bookstore. He received his B.S. in geology from the College of Charleston in Charleston, South Carolina and worked for three years for the South Carolina Coastal Council on a barrier island erosion migration study before coming to Utah.

Bon Voyage!

Mike Ross, after several years in the Mapping group, went to ERM-Southwest Incorporated in Houston - back home again!

Bill Mulvey left to attend school at North Carolina State in Raleigh. He worked on a multitude of projects with the Applied group.

New Publications of the UGS

Geologic map of the Hildale quadrangle, Washington and Kane Counties, Utah and Mohave County, Arizona by E.G. Sable, 14 p., 2 pl., 1:24,000, 1995 Map 167 . . $6.00

Radon-hazard potential of the southern St. George basin, Washington County, and Ogden Valley, Weber County, Utah by B.J. Solomon, 42 p., 1995, SS-87 . . . . . $5.95

Bluebell field drill-hole database, Duchesne and Uintah Counties, Utah by C.D. Morgan, D.A. Sprinkel, and K.A. Waite, 23 p., 1 diskette, 1995 C-90DF $5.95

Geologic map of the Fountain Green South quadrangle, Sanpete and Juab Counties, Utah by A.W. Fong, 18 p., 2 pl., 1:24,000, 1995 MP-95-1. . . . . $6.00

Geologic map of the New Harmony quadrangle, Washington County, Utah by S.K. Grant, 14 p., 2 pl., 1:24,000, 1995 MP-95-2. . . . . $6.00

Geologic map of the Richmond quadrangle, Cache County, Utah and Franklin County, Idaho by Jon Brummer and J. McCalpin, 22 p., 2 pl., 1:24,000, 1995 MP-95-3 . . . . $6.00

A collector's guide to rock, mineral & fossil localities of Utah by J.R. Wilson, 148 p. + color insert, 1995 MP-95-4. . . . . $8.95 ($9.95 for spiral bound)

Geologic hazards and land-use planning for Tooele Valley and the West Desert Hazardous Industry Area, Tooele County, Utah by B.J. Solomon and B.D. Black, 134 p., 56 pl., 1:24,000, Oct95 OFR-318 . . . . $94.00 (text $10.00, plates $1.50 ea)

Interim geologic map of the Moab quadrangle, Grand County, Utah by H.H. Doelling, M.L. Ross, and W.E. Mulvey, 141 p., 2 pl., 1:24,000, OFR-322 . . . . . . $24.00

Interim geologic map of the St. George quadrangle, Washington County, Utah by J.M. Higgins and G.C. Willis, 108 p., 2 pl., 1:24,000, OFR-323 . . . . $12.00

Interim geologic map of the Washington quadrangle, Washington County, Utah by G.C. Willis and J.M. Higgins, 108 p., 2 pl., 1:24,000, OFR-324 . . . . . . $12.00

Oil and gas pipeline map of Utah, by T.C. Chidsey Jr and P.B. Anderson, 7/95, 1 disk (in AutoCad 12 format) OFR-327DF. $20.00

Seismic source evaluation of the Salt Lake City segment of the Wasatch fault zone, central Wasatch Front, Utah by B.D. Black and W.R. Lund, 36 p., 8 pl., 10/95 OFR-328 . . . . $6.00

Guide to authors of geologic maps and text booklets of the Utah Geological Survey, by H. H. Doelling and G. C. Willis, 98p., C-89 . . . . $7.95

(Access to our publications list is available at http://utstdpwww.state.ut.us/~ugs/bookstor.htm)

Mail or Fax order to:
SALES
Utah Geological Survey
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Other Publications of Interest

(Not available from UGS)

A direct-current resistivity survey of the Beaver Dam Wash drainage in southwest Utah, southeast Nevada, and northwest Arizona, by A.A. Zohdy and others, 1994: USGS OFR-94-676

Geologic map of the Scarecrow Peak quadrangle, Washington County, Utah and Lincoln County, Nevada, by L.F. Hintze and G.J. Axen, 1995, USGS GQ-1759

Gravity and basin-depth maps of the Basin and Range Province, western United States, by R.W. Saltus and R.C. Jachens, 1995: USGS GP-1012

Geologic map of the Price 1 x 2 degree quadrangle, Utah, by I.J. Witkind, 1995: USGS I-2462

Western frontal fault of the Canyon Range - is it the breakaway zone of the Sevier Desert detachment?, by J.K. Otton, 1995: Geology, v. 23, no. 6

Salt budget for the West Pond, Utah, April 1987 to June 1989, by S.R. Wold and K,M, Waddell, 1994: USGS WRI-93-4028

Hydrogeology of recharge areas and water quality of the principal aquifers along the Wasatch Front and adjacent areas, by P.B. Anderson and others, 1994: USGS WRI-93-4221

Analytical data, sample localities, and basic statistical data for stream-sediment, heavy-mineral- concentrate, magnetite, and rock samples collected from the Goshute Indian Reservation, Nevada and Utah, by R.G. Eppinger and others, 1994: USGS OF-94-270A and B

Magnetotelluric data on and near the Goshute Indian Reservation, Utah and Nevada, by J.A. Sampson, 1994: USGS OF-94-296

Gravity, magnetic, and physical property data of the Deep Creek Range and vicinity, eastern Nevada and western Utah, by D.A. Ponce and V.E. Langenheim, 1993: USGS OF-93-397A and B

Utah areas of oil and gas production, by R.F. Mast and others, 1994: USGS OF-94-221

Preliminary geologic map of the Panguitch quadrangle, Garfield County, Utah, by D.W. Moore and A.W. Straub, 1995: USGS OF-95-9

Geologic map of Kious Spring and Garrison 7.5′ quadrangles, White Pine County, Nevada and Millard County, Utah, by A.J. Mcgrew and E.L. Miller, 1995: USGS OF-95-10

Pink topaz from the Thomas Range, Juab County, Utah, by E.E. Ford and others, 1995: The Mineralogical Record, v. 26, no. 1

Eocene extension of early Eocene lacustrine strata, in a complexly deformed Sevier- Laramide hinterland, northwest Utah and northeast Nevada by C.J. Potter and others: Geology v. 23, no. 2, Feb. 1995, p. 181-184.

Green River petroleum system, Uinta Basin, Utah, U.S.A., by T.D. Fouch and others: AAPG Memoir 60, 1994, p. 399-421.

The role of salt in the structural development of central Utah, by I.J. Witkind, 1994, 145 p., USGS Professional Paper 1528.

Hydrogeology of Jurassic and Triassic wetlands in the Colorado Plateau and origin of tabular sandstone uranium deposits by R.F. Sanford, 1994, 40 p., USGS Professional Paper 1548.

Solution-collapse breccia pipes of Spanish Valley, southeastern Utah, by G.W. Weir and others, 1994, 33 p., 1 pl., USGS Open-File Report 94-0417.

Bibliography of U.S. Geological Survey water-resources reports for Utah, 1886-1993 by E.E. Hardy and S.L. Dragos, 1994, 74 p., USGS Open-File Report 94-0309.

Stratigraphic and time-stratigraphic cross sections; a north-south transet from near the Uinta Mountain axis across the Basin and Range transition zone to the western margin of the San Rafael Swell, by D.A. Sprinkel, 1994, USGS Miscellaneous Investigation Map 2184-D, 31 p., 2 sheets.

Geologic map of the Hatch Rock Quadrangle, San Juan County, Utah, by G.W. Weir and others, 1994, 13 p., 1 pl., 1:62,500, USGS Geologic Quadrangle 1722.

Correlation of the West Canyon, Lake Point, and Bannock Peak limestones (Upper Mississippian to Middle Pennsylvanian), basal formations of the Oquirrh Group, northern Utah and southeastern Idaho, by L.E. Davis and T.S. Dyman, U.S. Geological Survey, 1994, 30 p., 1 pl., B 2088.

Determination of hydrologic properties needed to calculate average linear velocity and travel time of ground water in the principal aquifer underlying southeastern Salt Lake Valley, by G.W. Freethey and others, 1994, 30 p., WRI 92-4085.

Cover photo: Spring flowing from the Weber Quartzite in Big Cottonwood Canyon. Photo by Gary Christenson.

Utah Geological Survey
2363 South Foothill Drive
Salt Lake City, UT 84109-1491

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Survey Notes

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